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Active Interrogation of SNM with NRF

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Disclaimer

Lawrence Livermore National Laboratory

Active Interrogation of SNM with NRF

Micah S Johnson

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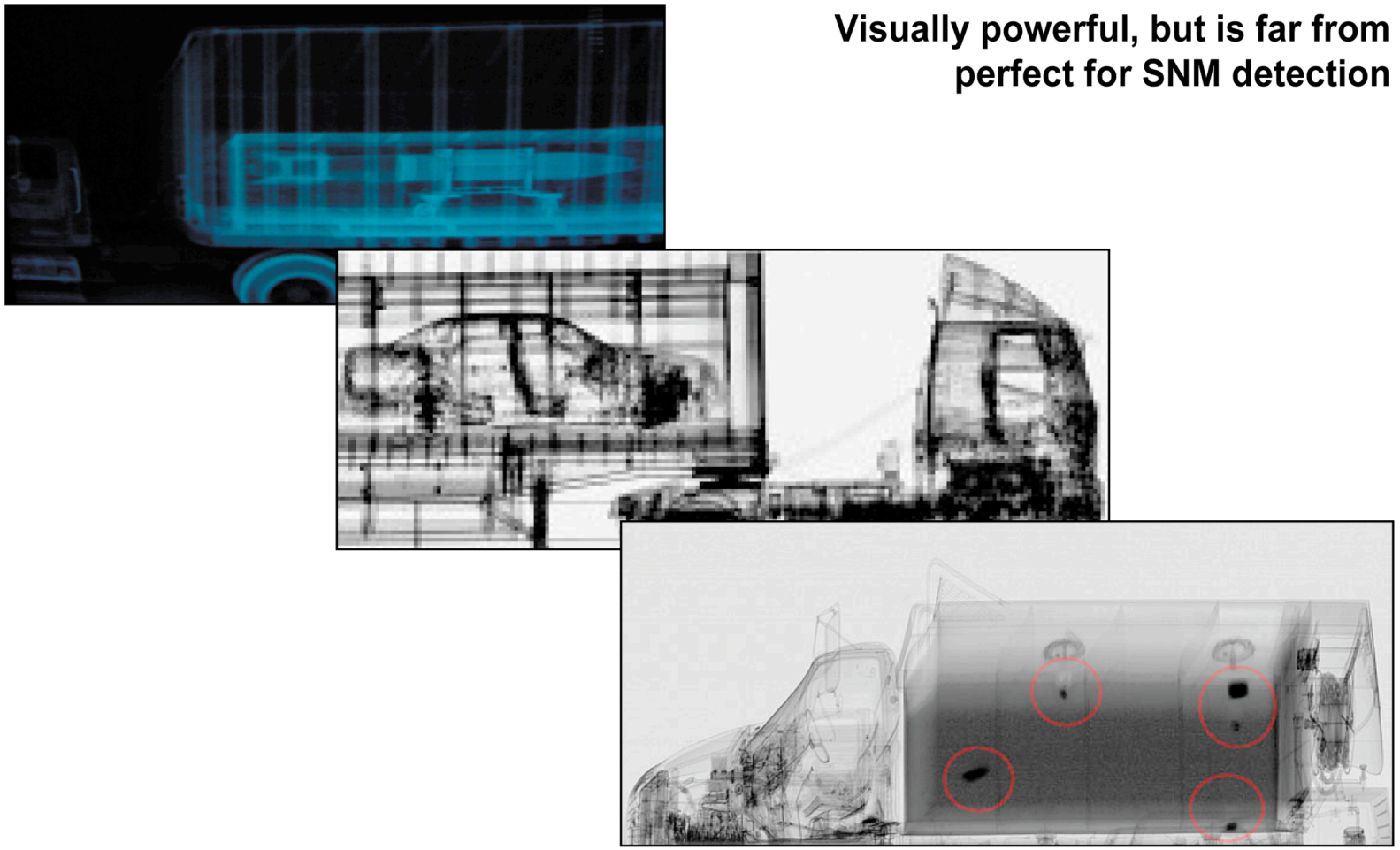
Outline

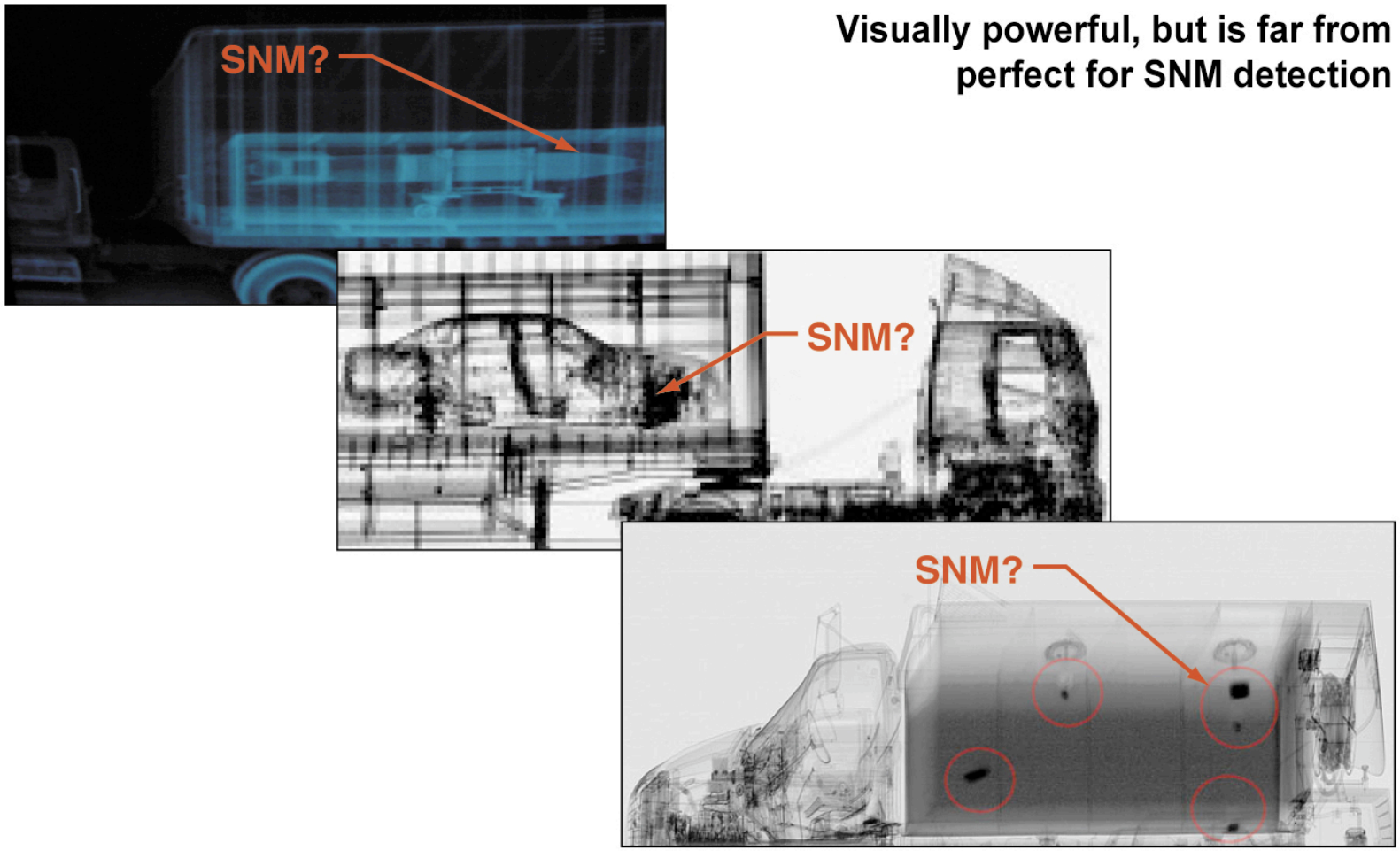
- Motivation for isotopic mapping - NRF scanning
- Background
- NRF scanning technology in development at LLNL
- Measurements of Pu
- Summary and future work

Current systems: radiography



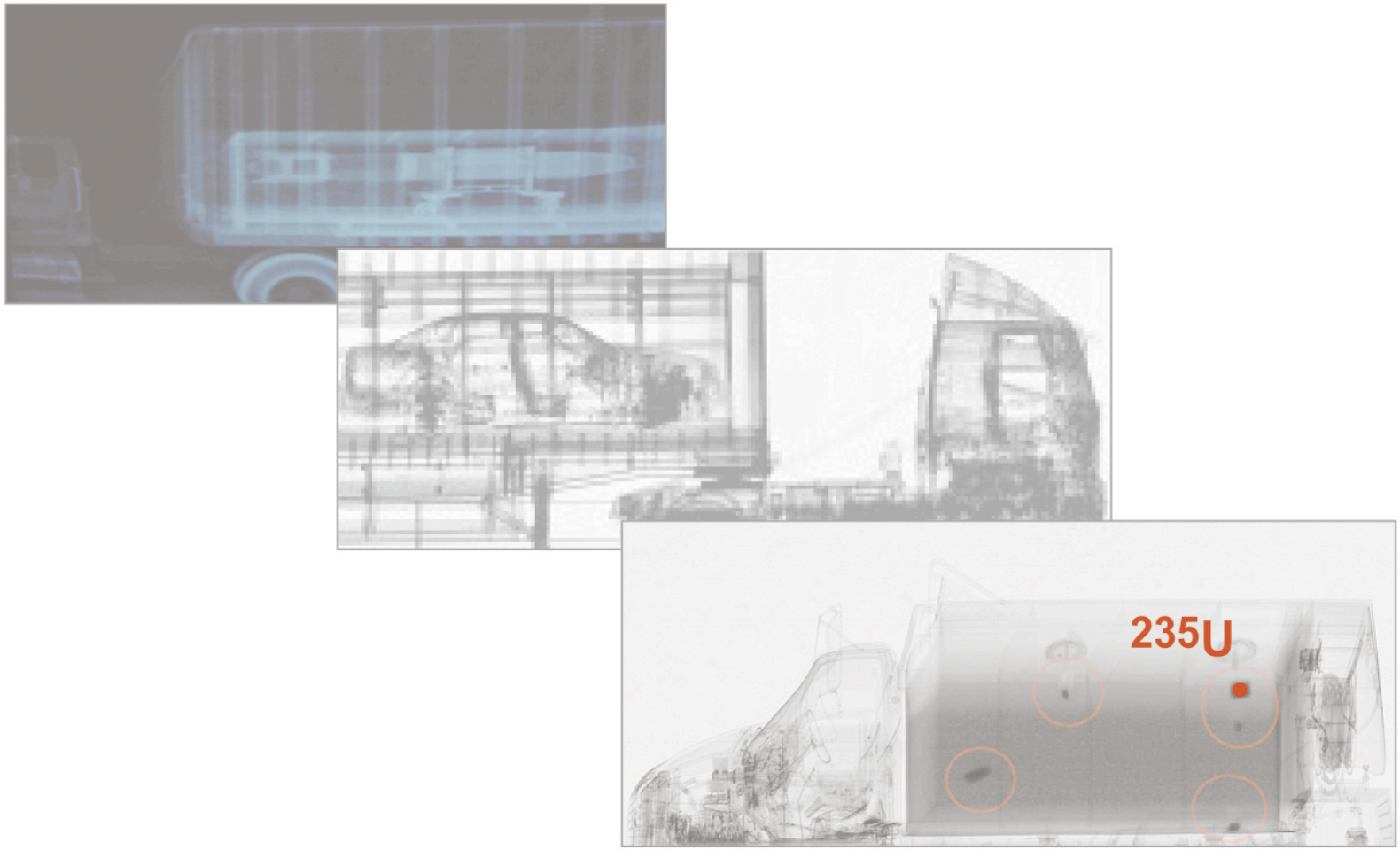
Visually powerful, but is far from perfect for SNM detection

Limitation: density silhouette



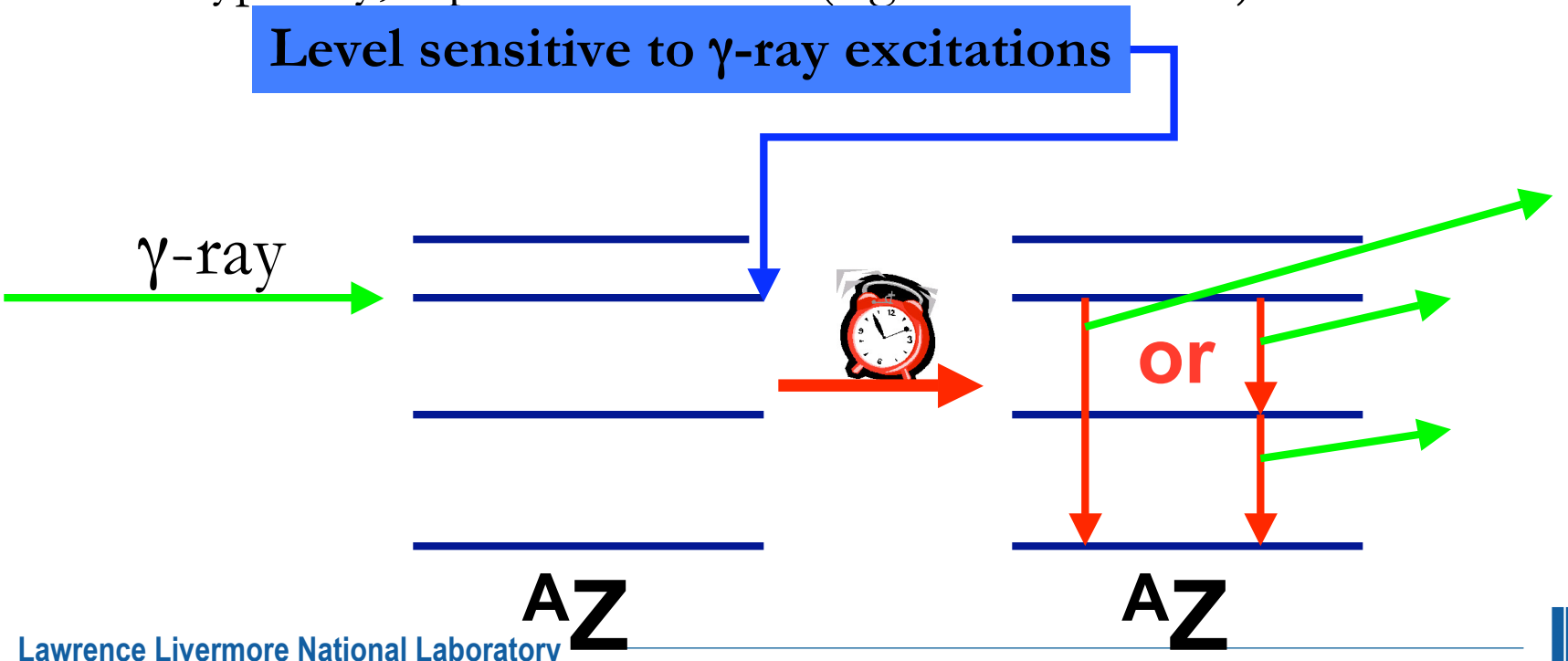
Visually powerful, but is far from perfect for SNM detection

NRF ⇒ isotopic sensitivity

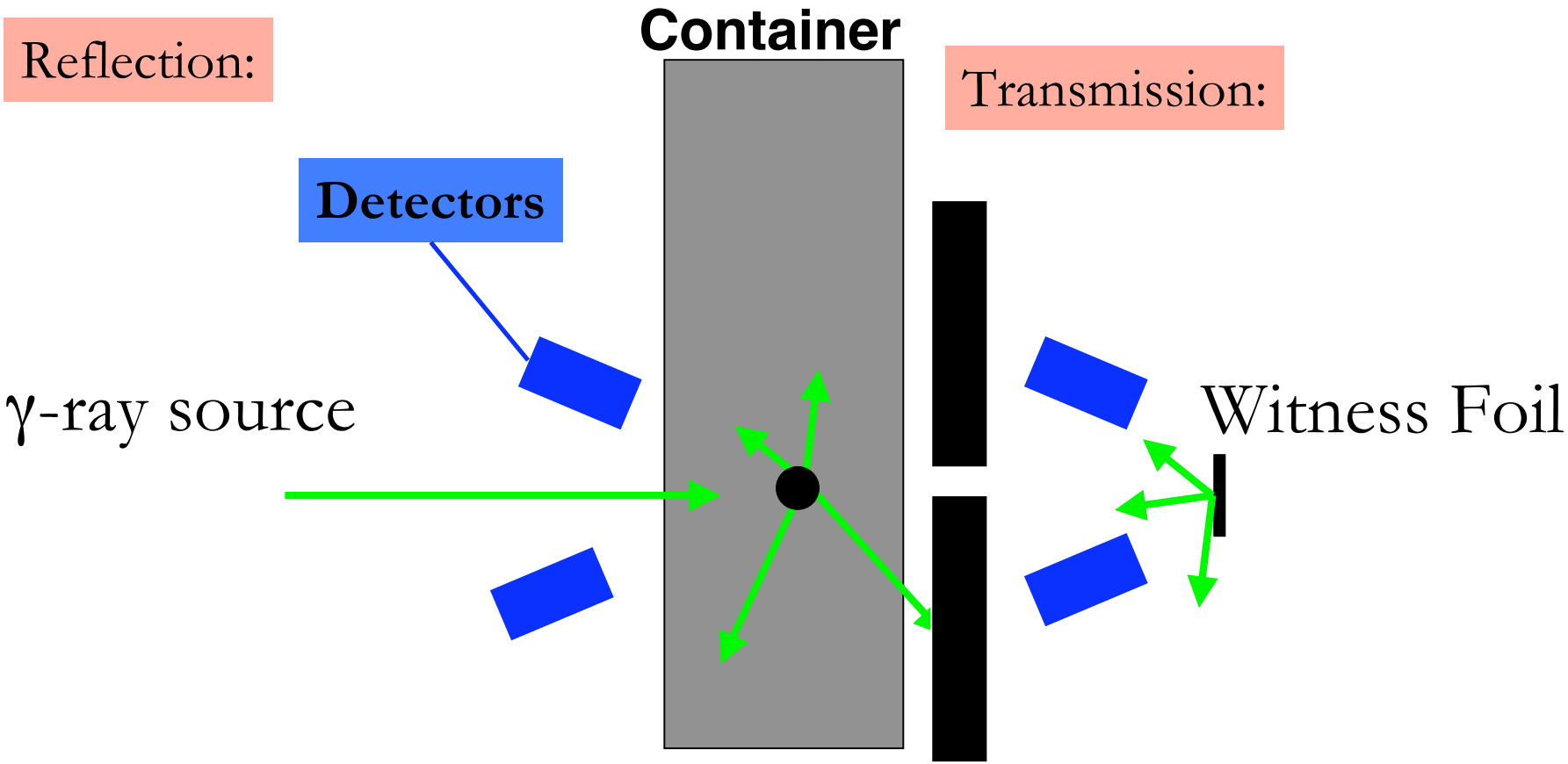


Nuclear Resonance Fluorescence (NRF)

- An energetic photon (γ-ray) at a resonant energy of a particular isotope can excite that isotope.
- The excited nucleus then will decay by emitting a set of γ-rays
- Typically, dipole excitations (e.g. scissors mode)

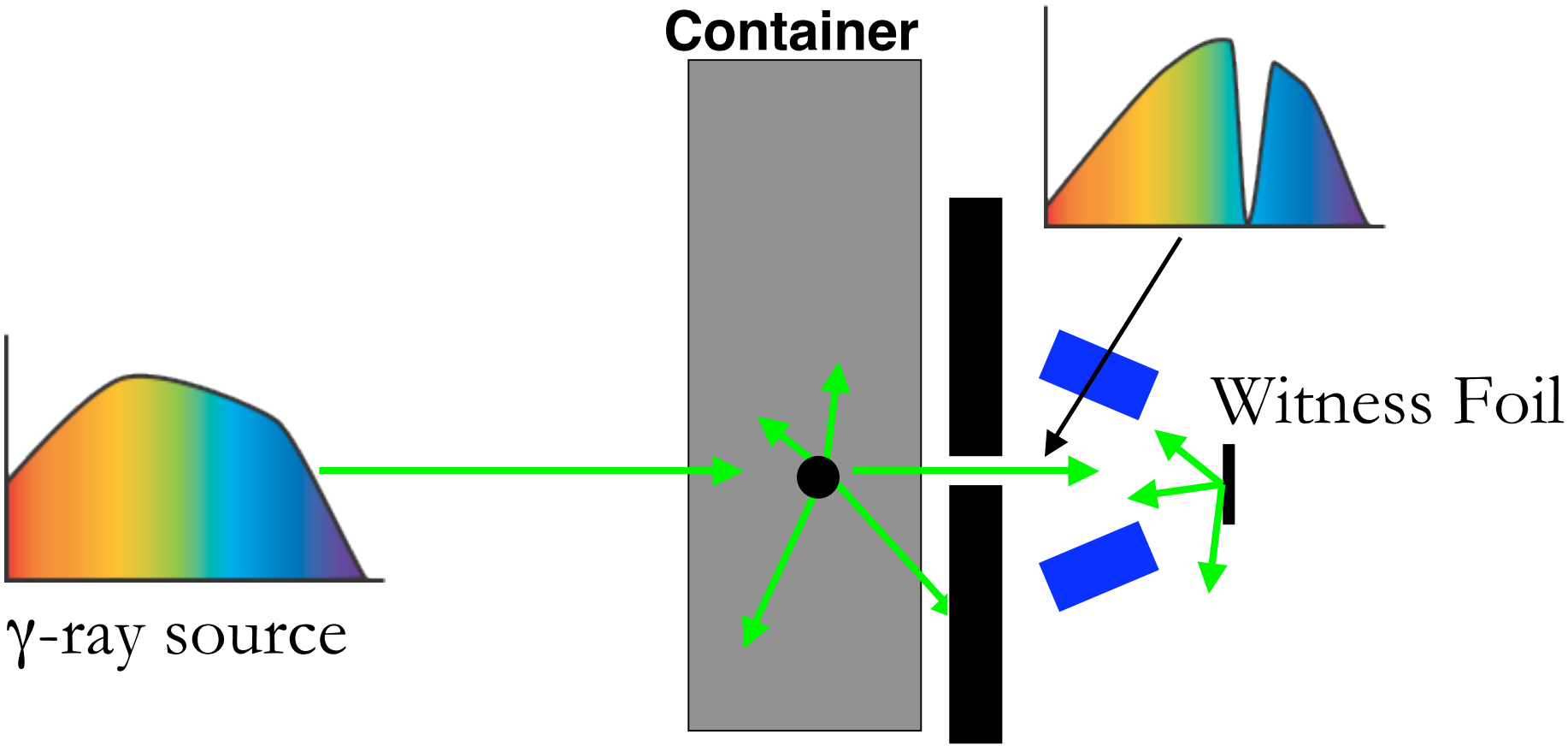


Schematics of proposed NRF scan techniques



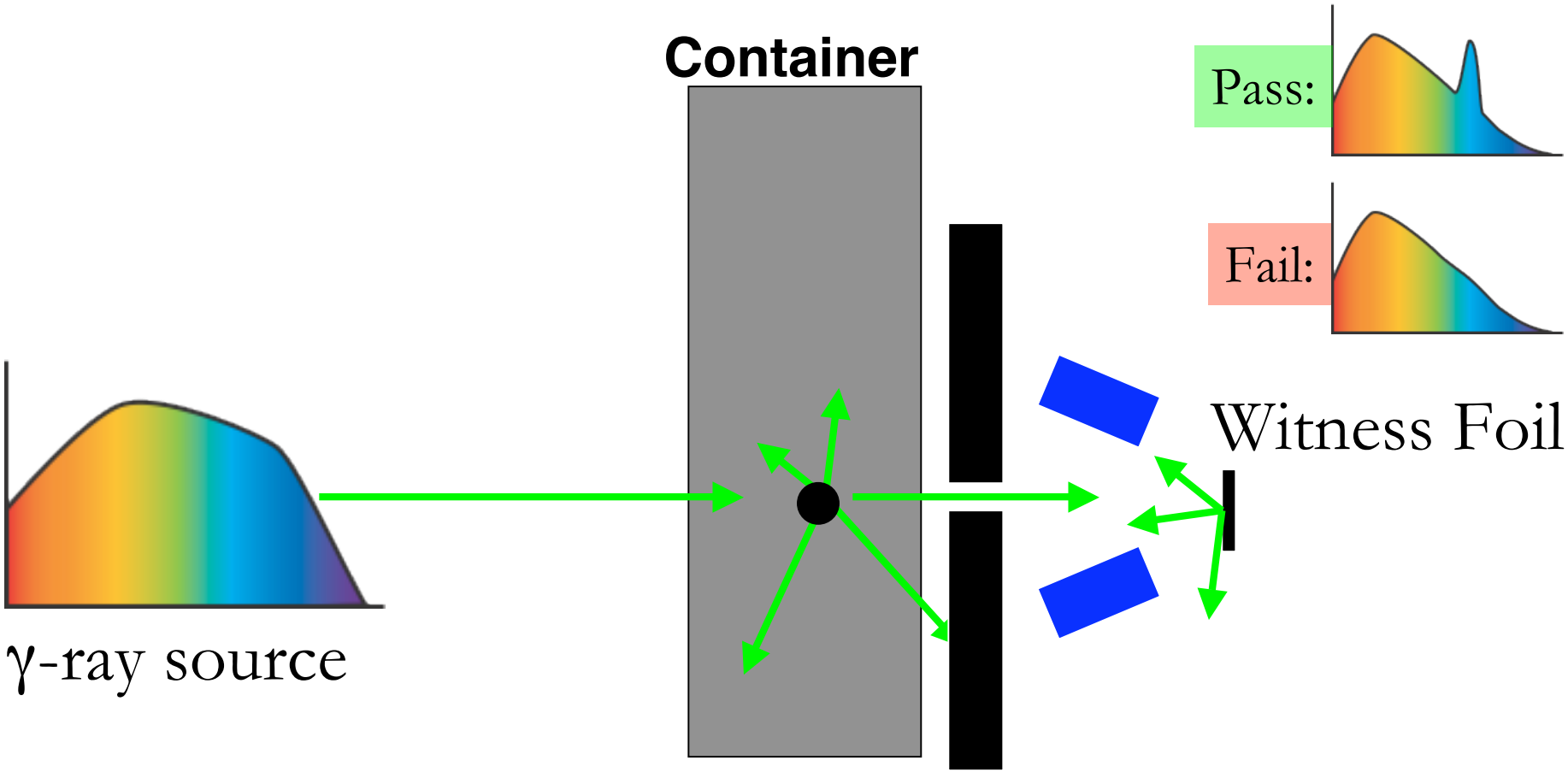
Transmission: scatter occurs in container **OR** from witness foil

Transmission technique



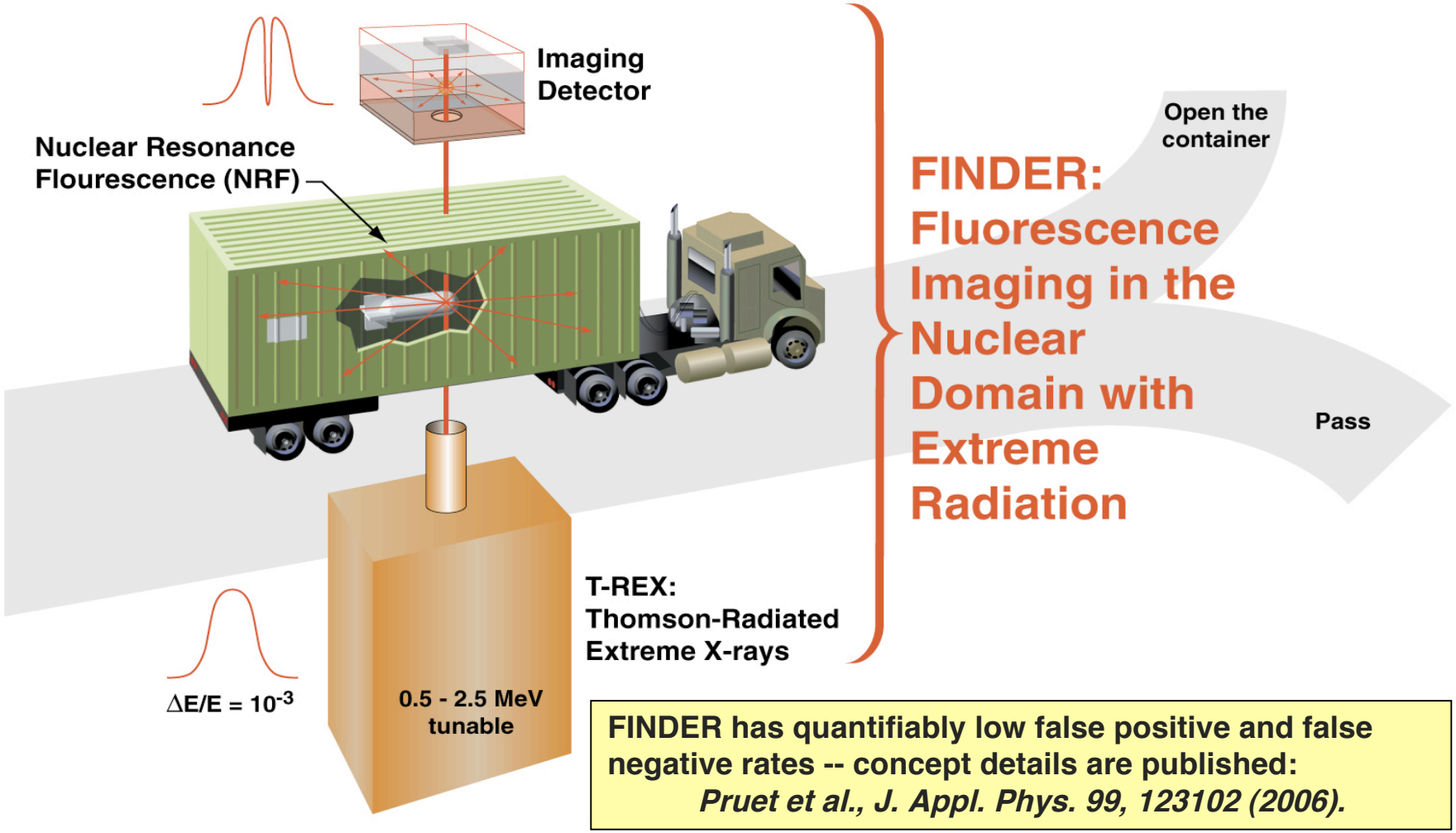
If material is present then the incident spectrum obtains a notch

Transmission technique



Scatter from witness foil exposes NRF lines **OR** not

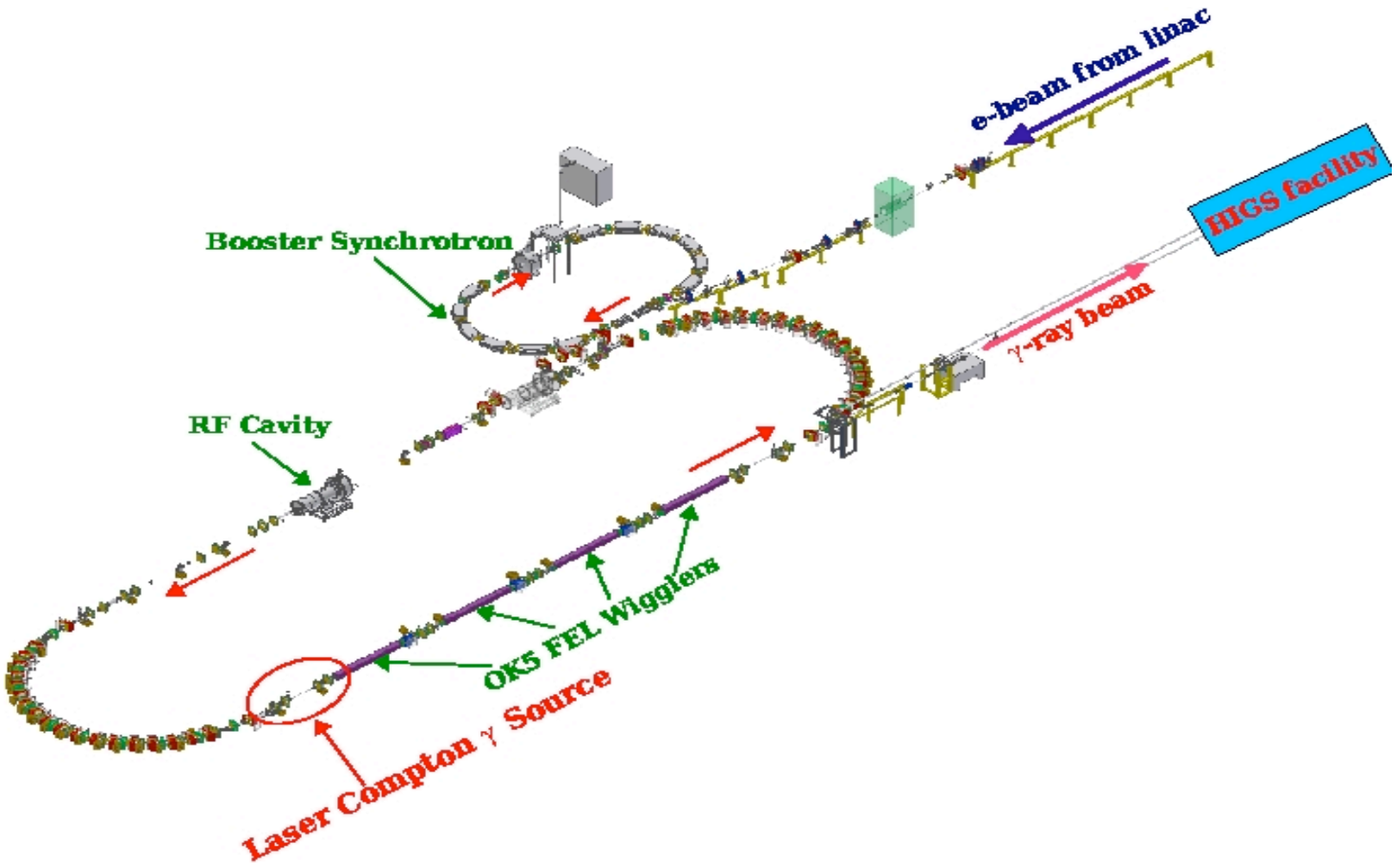
LLNL concept: FINDER



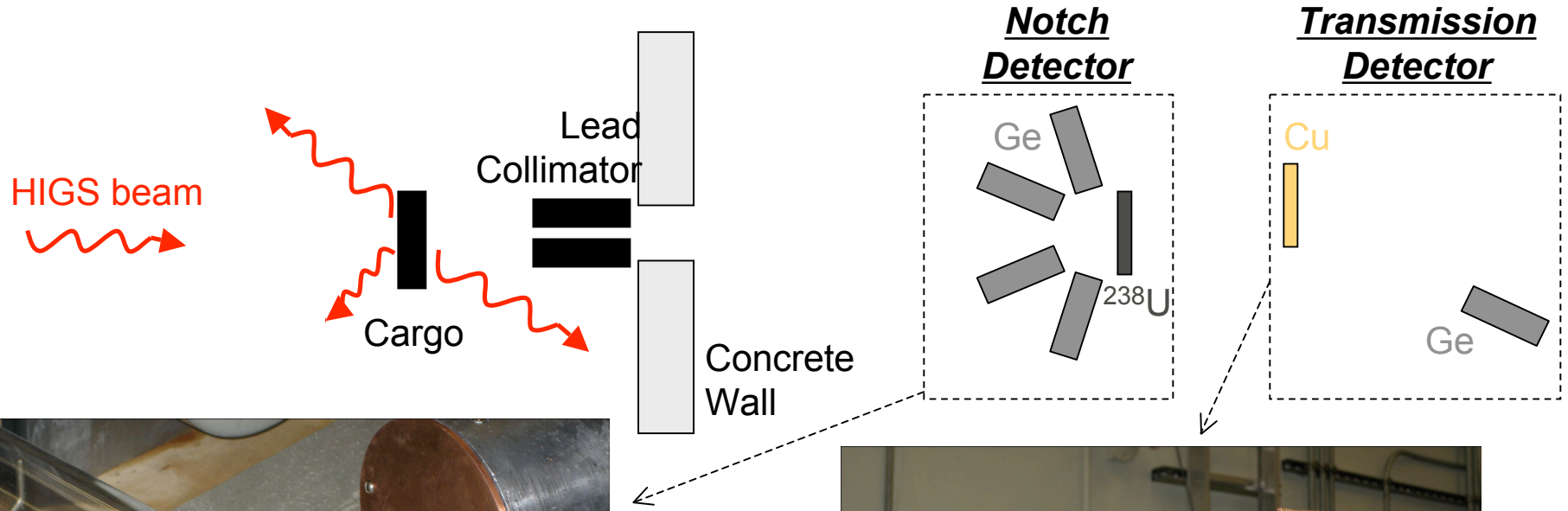
FINDER has quantifiably low false positive and false negative rates -- concept details are published:

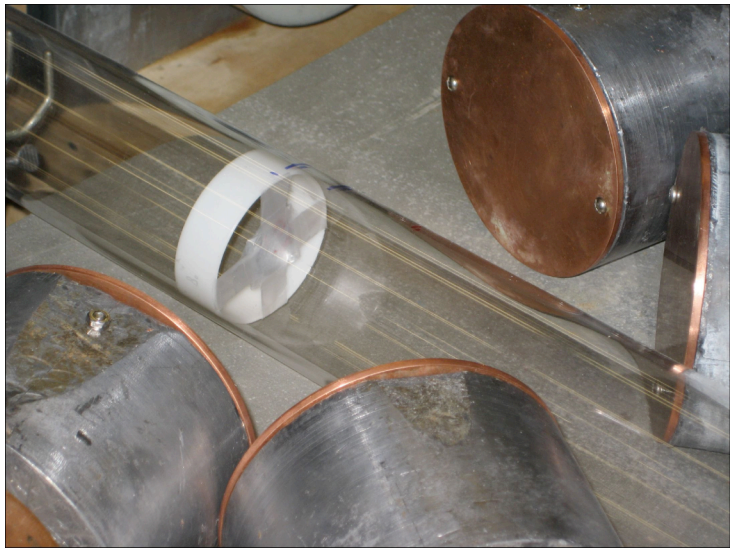
Pruet et al., J. Appl. Phys. 99, 123102 (2006).

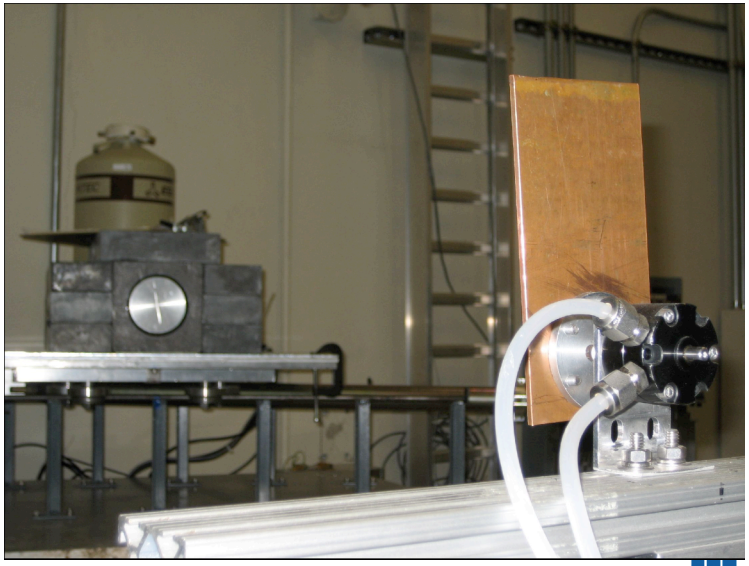
HIgS


e-beam from linac
HIGS facility
Booster Synchrotron
γ-ray beam
RF Cavity
OK5 FEL Wigglers
Laser Compton γ Source

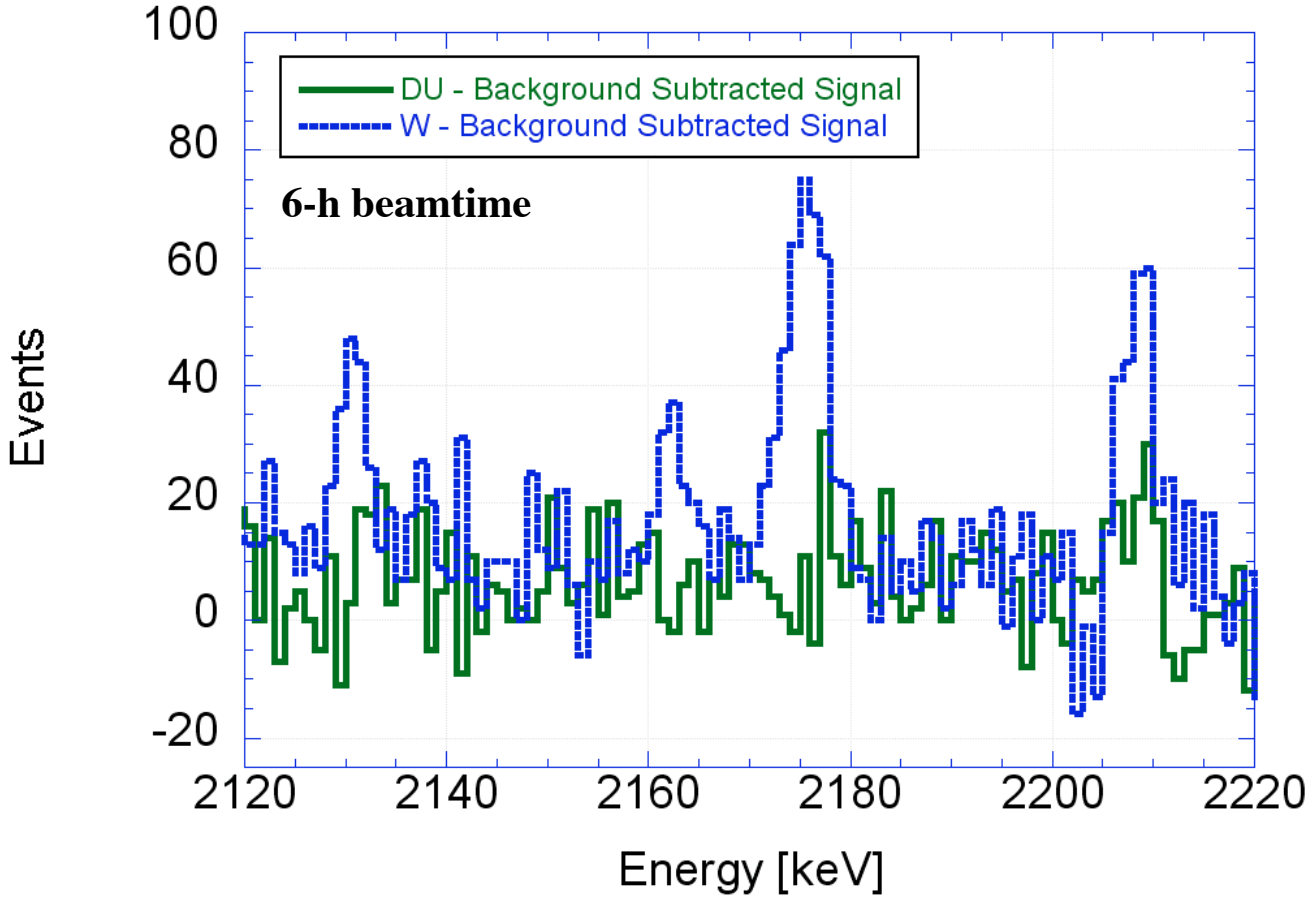
Validation measurement for the transmission technique, Experimental setup at HIGS



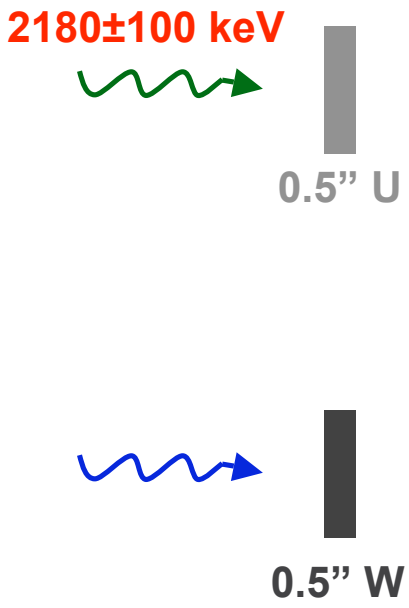




LLNL demonstrated transmission detection

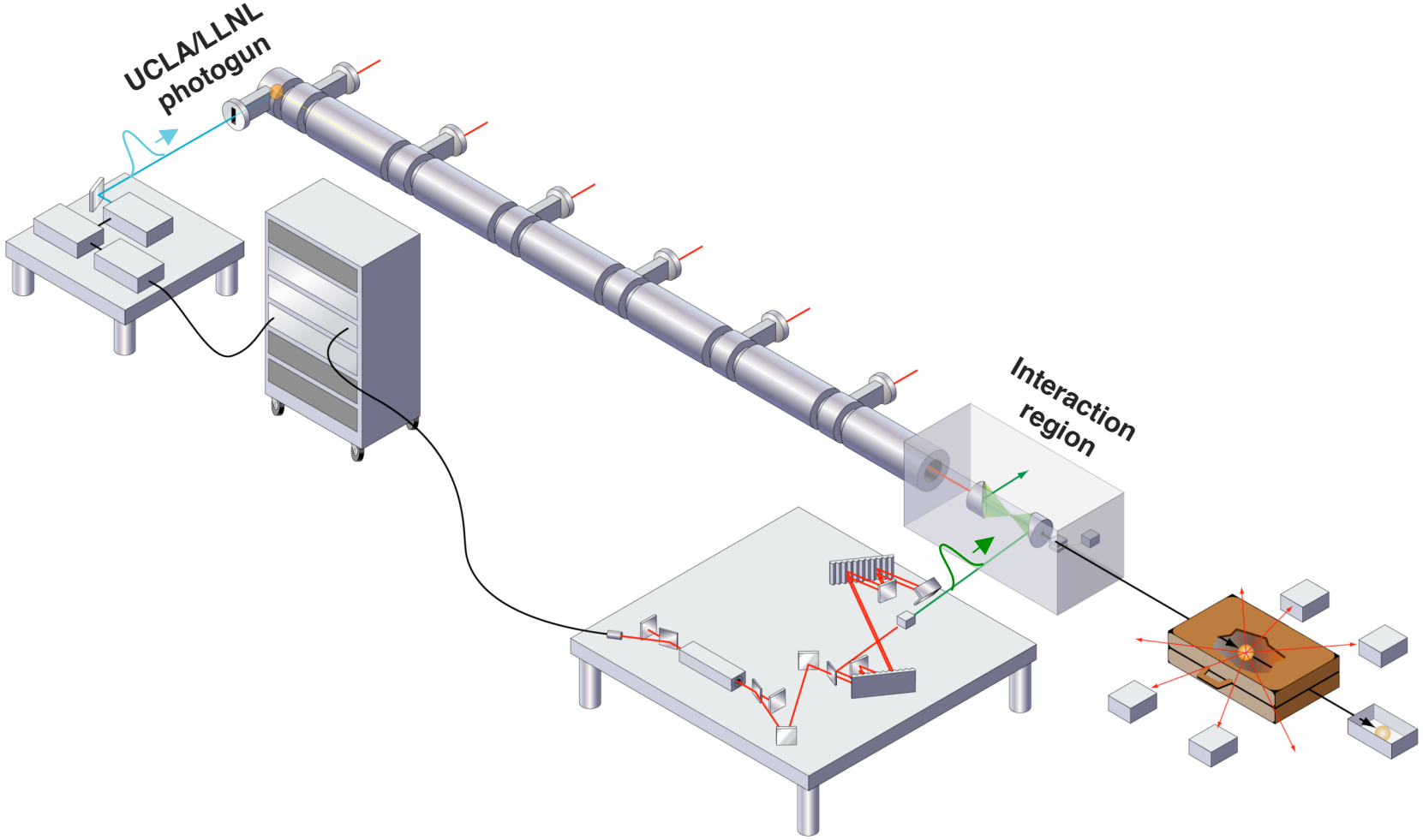


Cargo scenarios

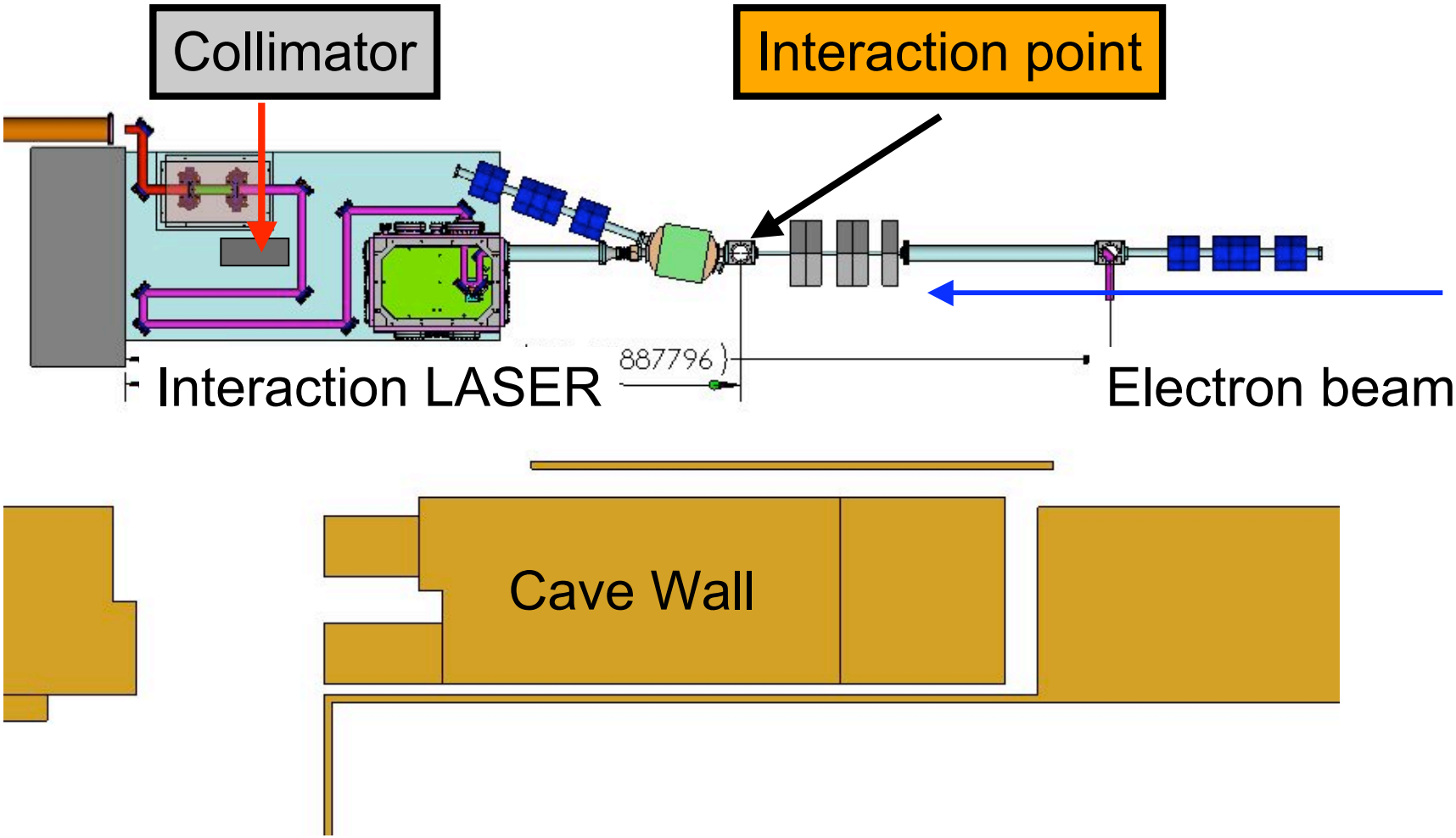


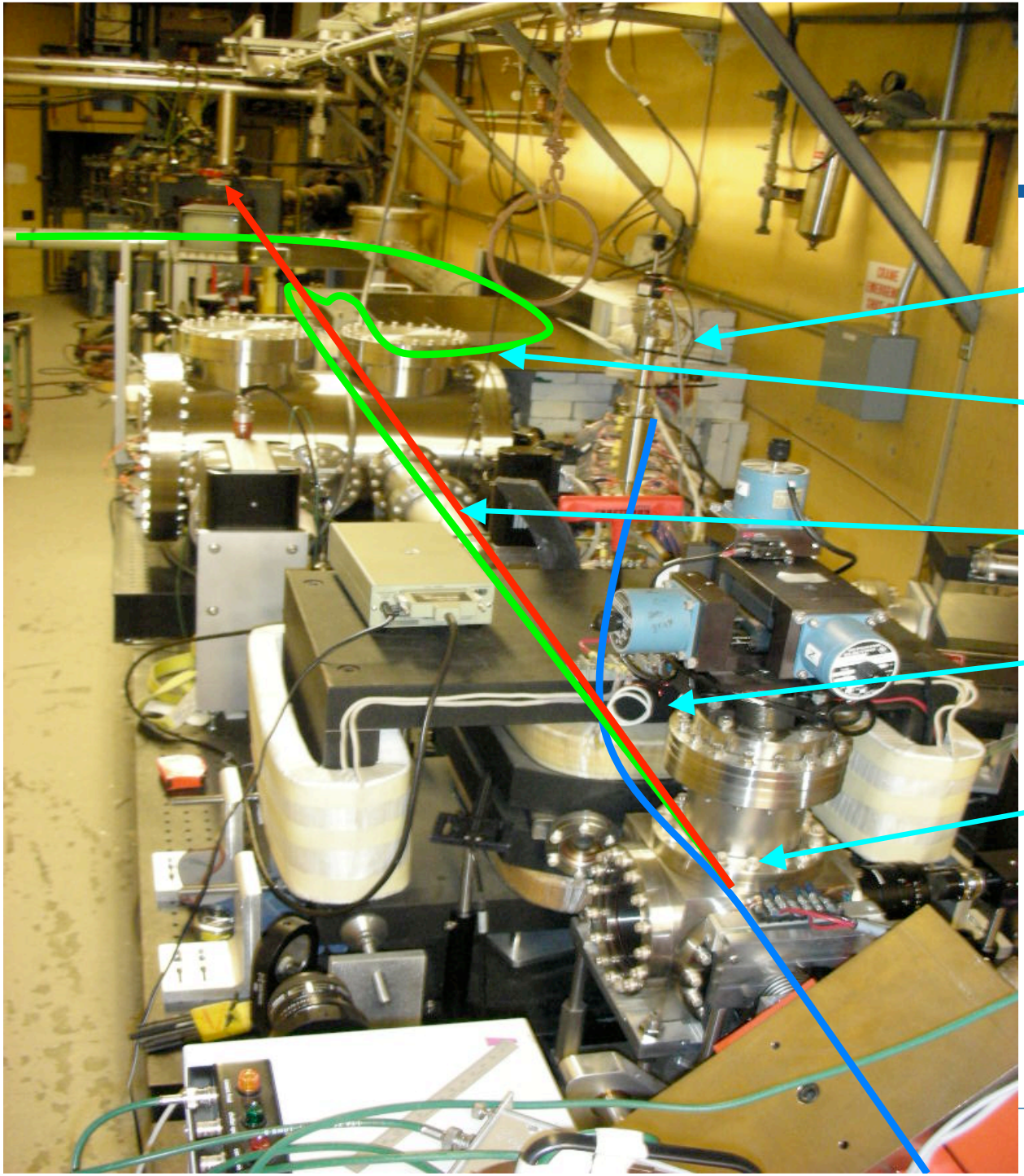
DU peaks imply the absence of DU in cargo

T-REX schematic

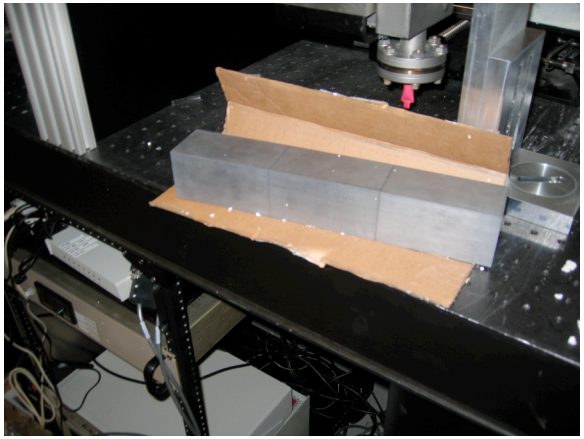


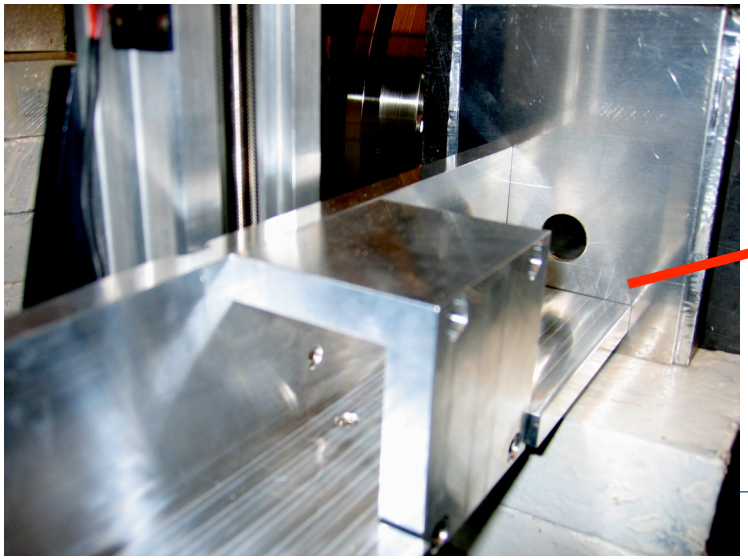
T-REX: Interaction layout

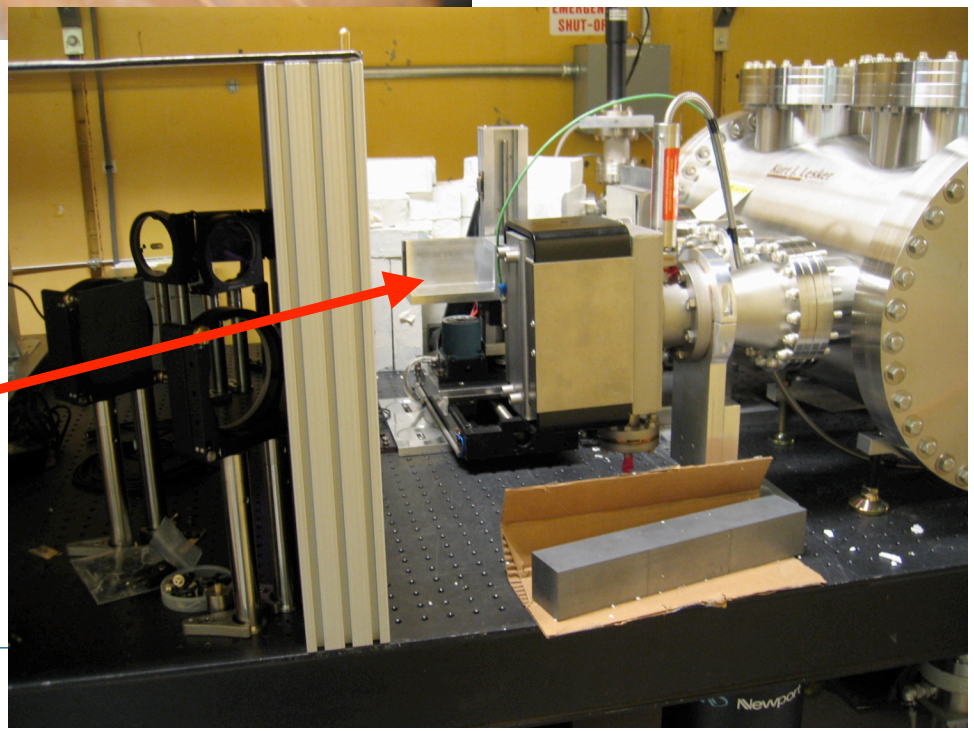



Electron beam dump
Laser
Photons
Dipole magnet
Interaction region

Collimator

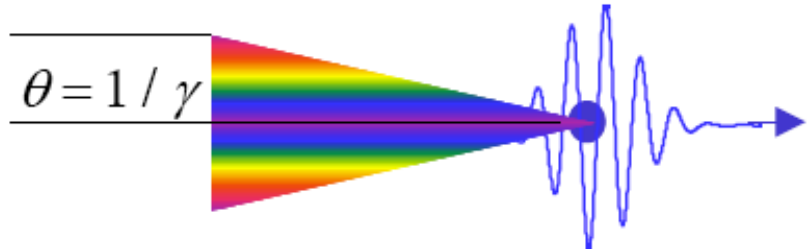






T-REX photon production

$$\omega_s(\theta) = 4\gamma^2 \omega_{laser} \frac{1}{1+\gamma^2\theta^2}$$



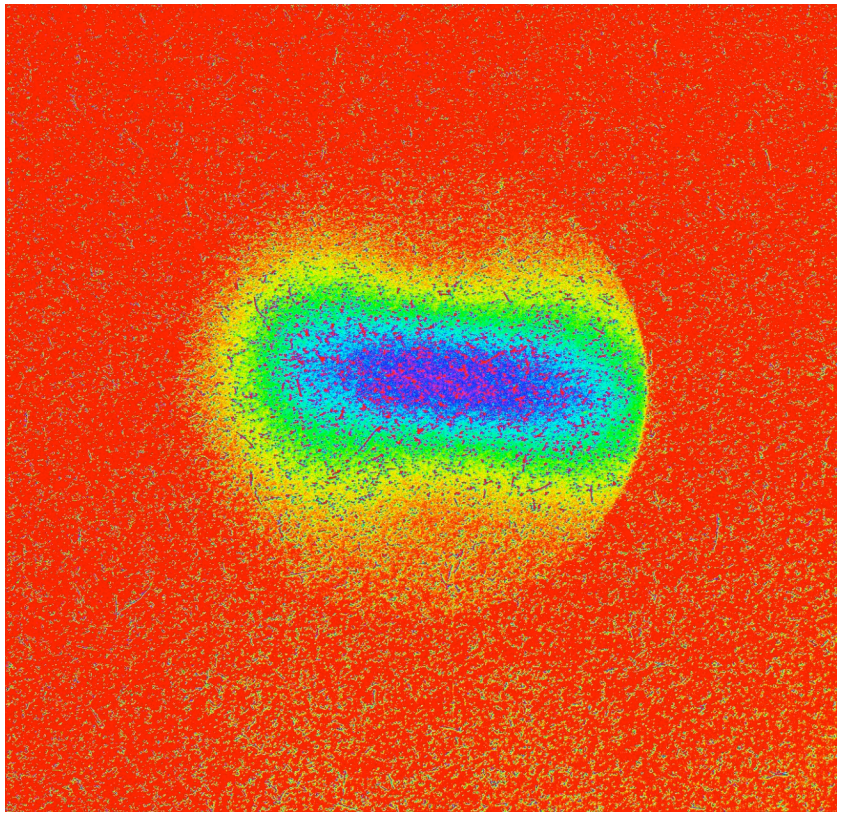
- Electron beam and laser beam are timed so that they reach the interaction point simultaneously
- Electron wiggles in the field of the photon and produces changing field of its own
- In the lab frame, this translates to energetically boosted, forward focused x-rays.
- Electron beam is 112 MeV, laser beam is 510 nm (2.4 eV)

  ⇒**480 keV**

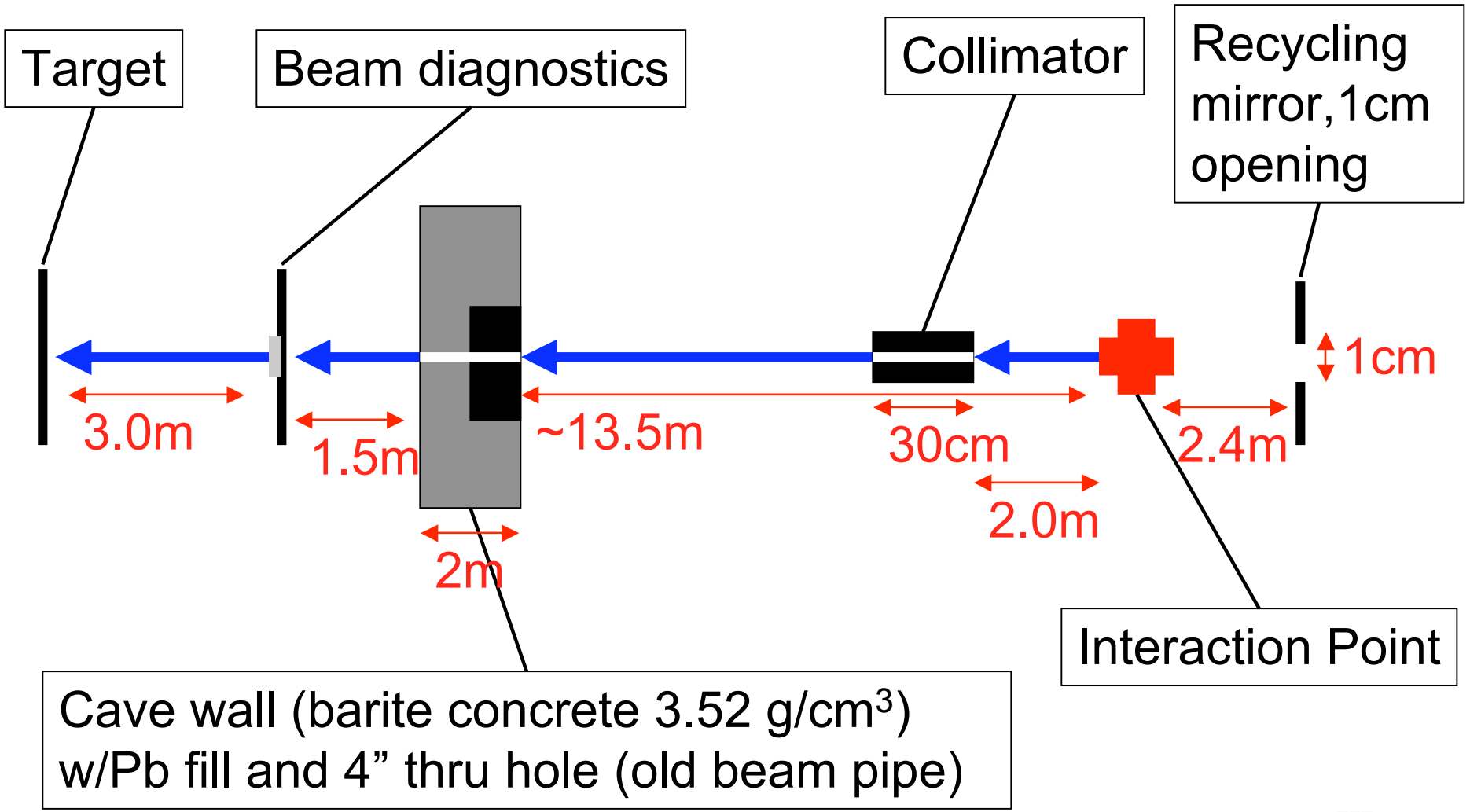
  - Necessary for demo on ^{7}Li

T-REX First Light

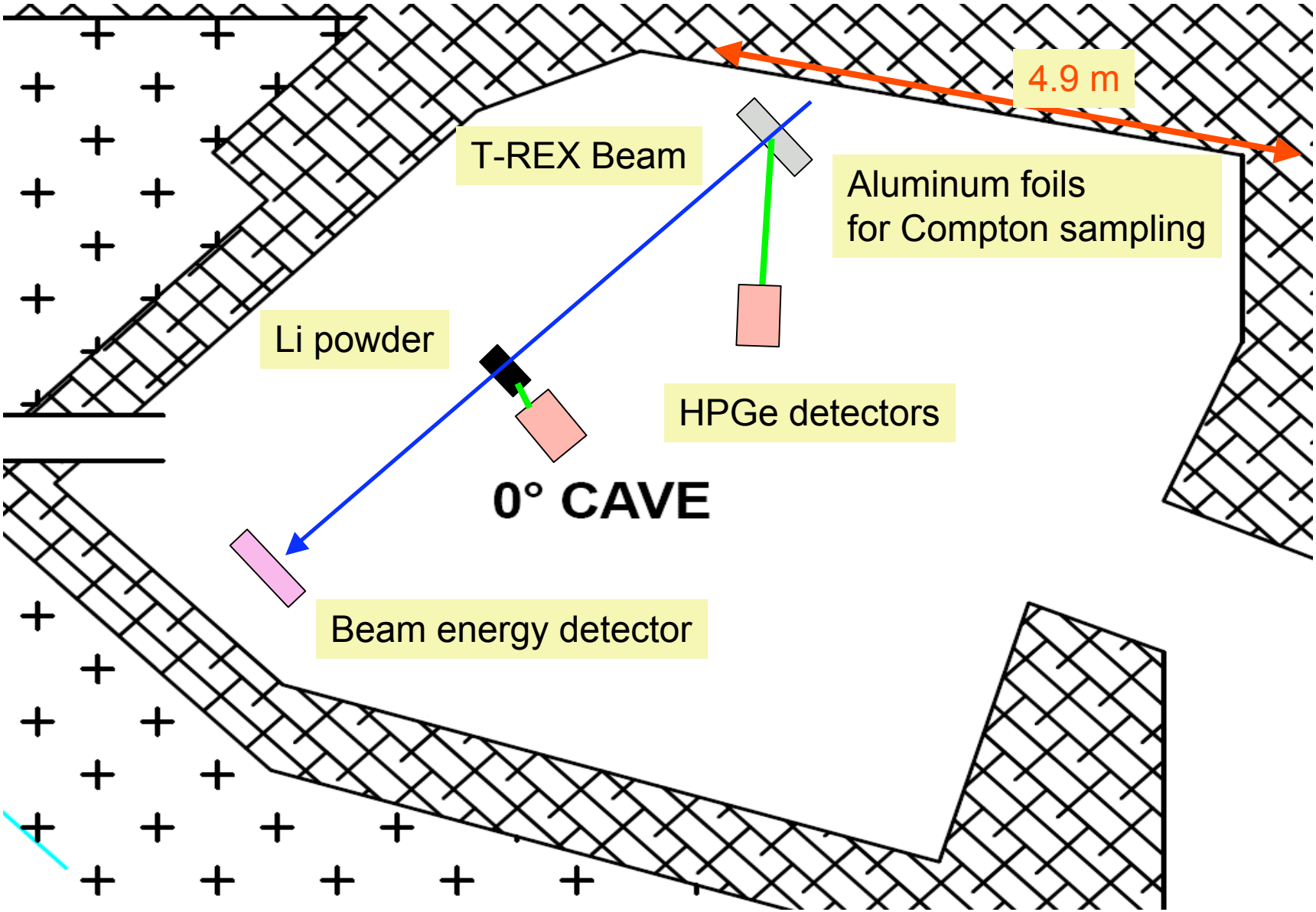
- Monday, Feb 25, 2008
- 1064 nm + 120 MeV = 260 keV
  - 1064 nm = infrared
- Picture: intensity image
- Circular feature is 1.75” diameter
- Field of view is 4” each side



Flight-Path for demo

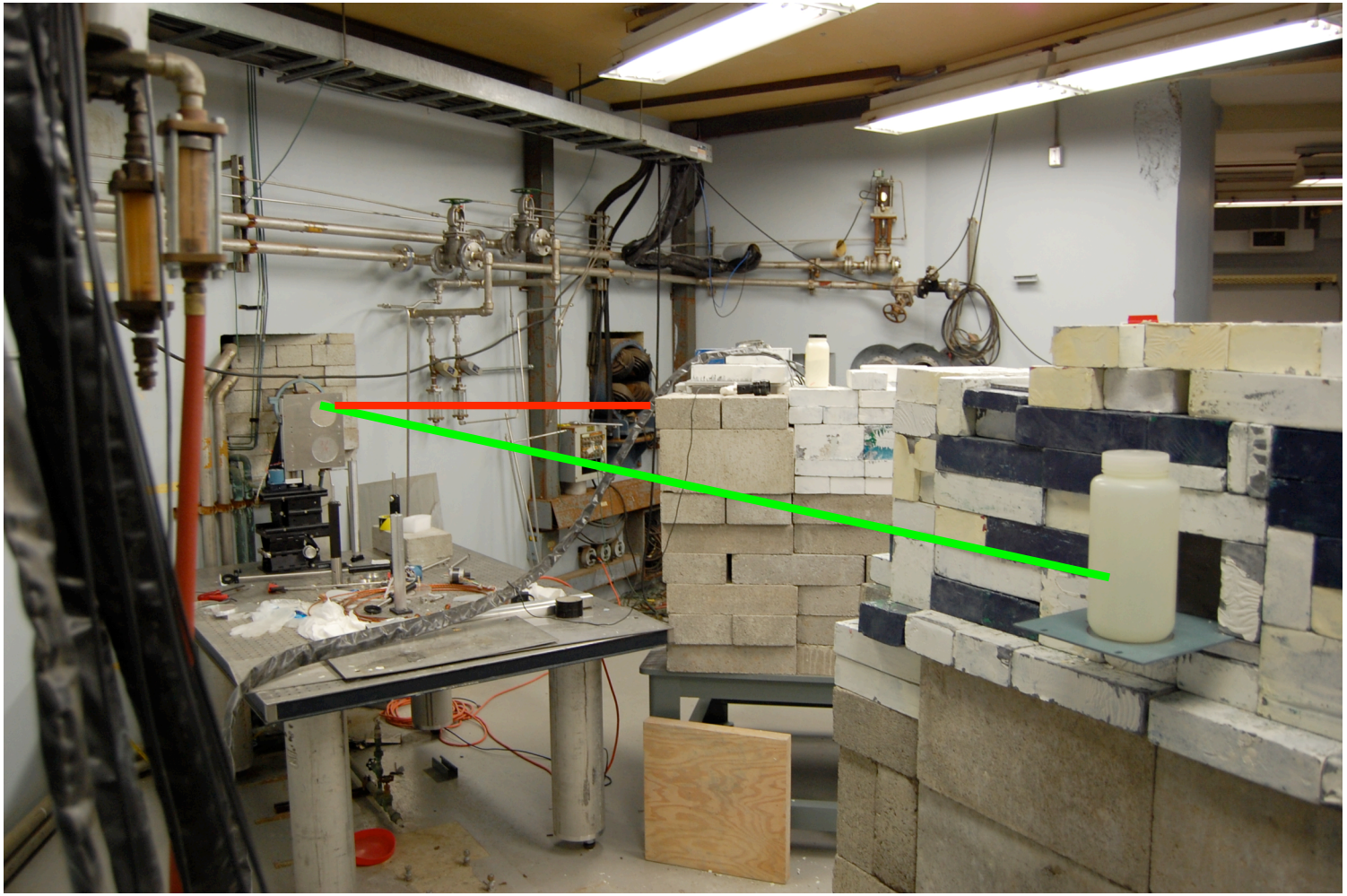


FINDER demo layout



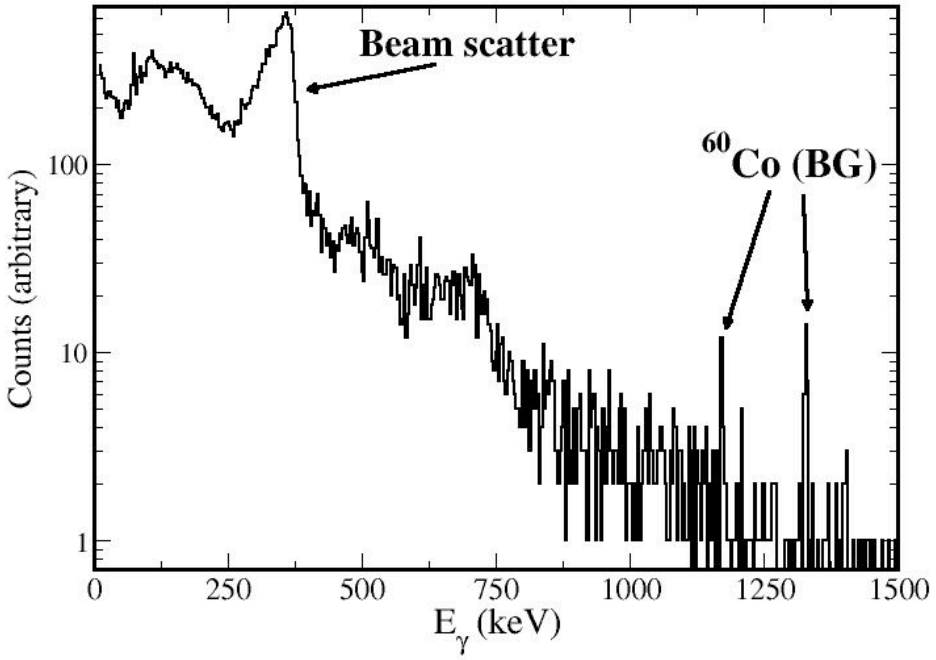

Al foil
HPGe detectors
Li target
Beam monitor

LiH setup



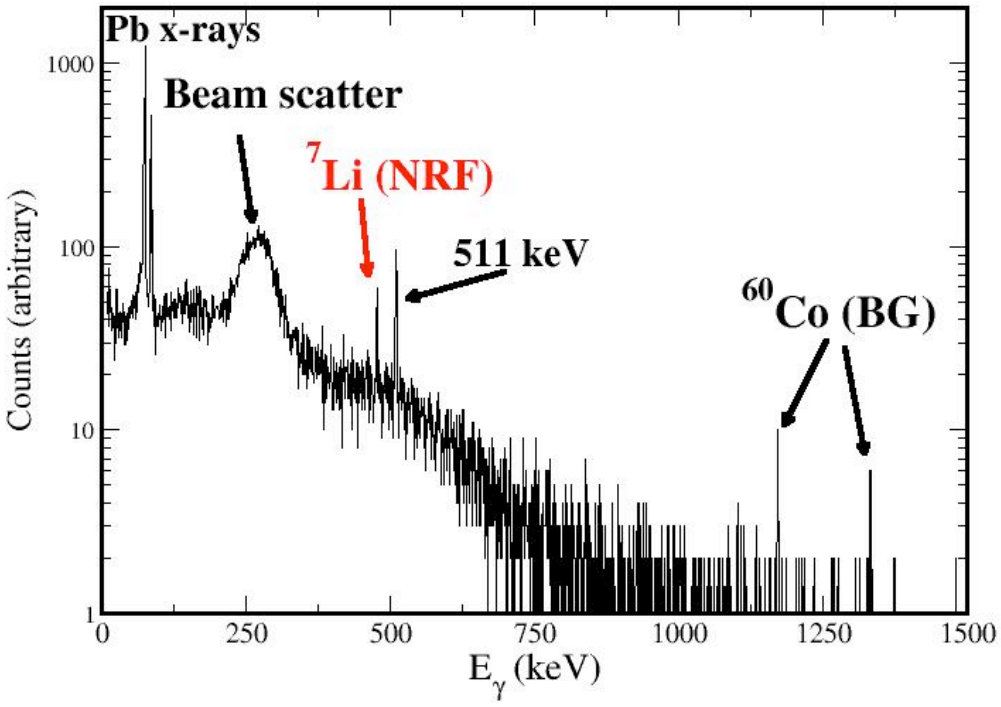
LiH demonstration

- Plot is spectrum taken from HPGe focused on Al plate.
- Detector is 48 degrees from beam axis
- 50% HPGe
- RF gated
- Beam is tuned to 480 keV



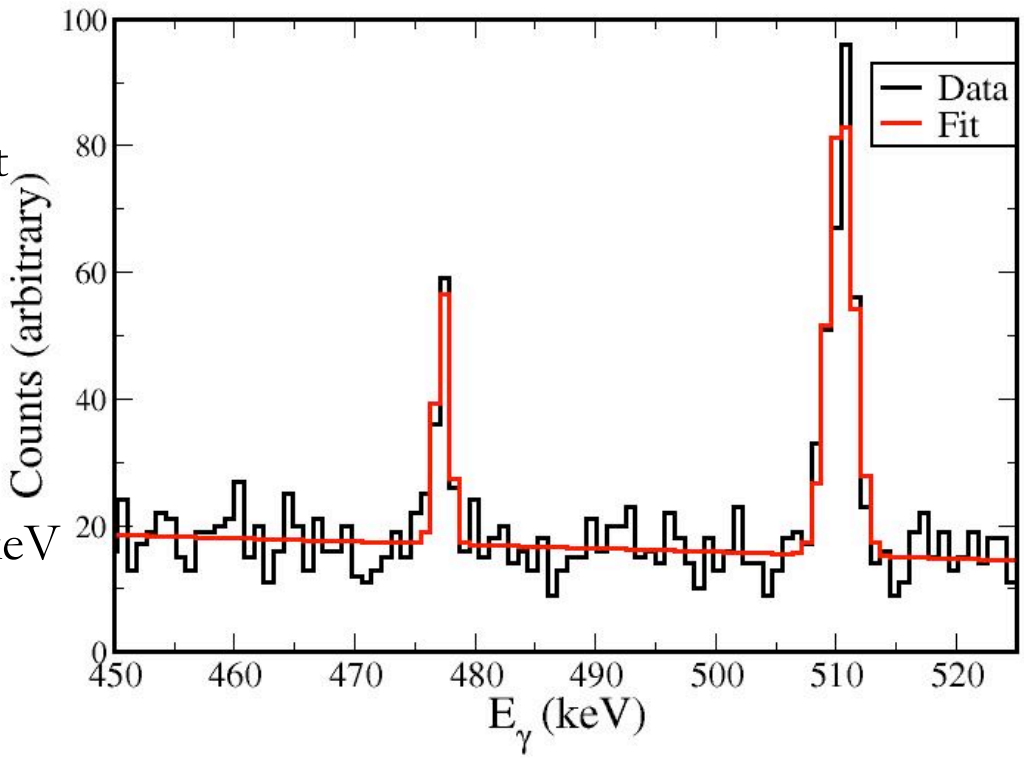
LiH demonstration

- Plot is spectrum taken from HPGe focused on LiH target.
- Detector is 90 degrees from beam axis
- 50% HPGe
- RF gated
- Beam is tuned to 480 keV



LiH demonstration

- Plot is spectrum taken from HPGe focused on LiH target.
- 511 keV is present
- 477 keV Li NRF peak is present
- Fit results
  - Chi-squared = 0.938
  - Sigma (477) = 6.727
  - Centroid = 477.63(19) keV
    - ENSDF = 477.612(3) keV
  - Width (477) = 2.43 keV
    - Consistent with calibration source



Summary

- NRF measurements have been performed on ^{239}Pu 2.5 MeV
  - Presentation at DNP
- Demonstration of notch detector was performed at HIgS
  - Used DU as a target material
  - Beam energy was 2.18 MeV (2% bandwidth)
  - NRF scatter from witness foil with no DU as "cargo"
  - No NRF scatter from witness foil with DU as "cargo"
- Demonstration of TREX source was performed
  - Beam tuned to Li
  - NRF state in Li at 477 keV was seen
  - On axis measurements of beam was overwhelmed by background

Outlook

- NRF measurements on other materials of interest to national security
  - Approved proposal
  - HIgS
- Demonstration of reflection versus transmission modes at HIgS
  - December measurements
- Need to better understand the sources of background for next generation gamma ray facilities

Collaboration

- M.S. Johnson, D.P. McNabb, C.A. Hagmann, *LLNL*
- TREX folks
- B194 operators